ON THE COMBINED OBSERVATIONS OF THE CRUSTAL DEFORMATION AT SOME OBSERVATORIES IN THE SHORT INTERVALS

BY

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1. It is all-important for the study of the crustal deformation to confirm whether the anomalous changes among the observed phenomena show the anomalous deformations over the large area or not. The area of the deforming crust can't be estimated by an observation at only one point or by the one of a very short measuring line[1, 2]. And also, it is nonsense in most cases to compare the observations with the ones at the very distant observatories, because the relationships between these observations have never clear.

An extensometer with a long span and a water tube tiltmeter with the same are appropriate a little for the above purpose. But, their spans are often limited by the instrumental conditions and the site. Therefore, it needs to set some observatories at the short intervals or to do densely those in the specific area.

The present author has set two groups of the highly sensitive extensometers[3] which he has devised and two pairs of the tiltmeters at both sides of the observatory where the observations has been being performed from 1947[4] at Osakayama Observatory, then he has begun to perform the combined observations at these three observatories in December, 1959. From these observations, he has calculated a wave length of the annual variation of the linear strain, and has researched the phenomena before and after the strong earthquakes and the other natural disturbances of the ground.

2. These combined observations are being performed at Osakayama Observatory. Osakayama Observatory is situated in lat. 34°59.6′N. and long. 135°51.6′E., and the instruments are equiped about 100 m. under the ground. The wave lengths of the crustal deformation which are noteworthy on the disastrophism and seismology are still unknown. And the elastic energies of the crustal strain would be sometimes considerable quantities for the seismic energy even if in the states which the volumes of the anomalously strained crust are only several hundred metres cube. And the intervals of the dispositions of the observatories under the same conditions are restricted by the dimension of the gallery. And so these three

observatories are placed at their intervals of about 150 metres and about 200 metres on a straight line; No. 3 observatory is situated between 150 m. and 180 m. from Ōtsu-entrance, No. 1 Observatory is between 310 m. and 380 m. from there, and No. 2 observatory is between 490 m. and 520 m. from there, respectively.

Table 1 (a)

The Constants of Extensometers

Symbol of Instrument	Direction of Observation	Type of the Instrument	Span of Observation	Sensibility of the Instrument $\times 10^{-8}$/mm	Epoch of Observation	Position of Observation from Ōtsu Entrance
L2	S38°W	H-59-B-type	12 m	0.422~0.620	Mar 1961	500 m
W1	S38°W	Sassa-type	20	1.20	Oct. 1947	370
R1	S38°W	Roller-type	19.6	1.30	Oct. 1951	370
L3	S38°W	H-59-B-type	26	0.0406~0.725	Dec. 1959	170
E1	E-W	H-59-B-type	5.3	0.241~0.777	Dec. 1958	310
E3	E-W	H-59-B-type	4.8	0.158-0.610	Dec 1959	170
N1	N-S	H-59-B-type H-59-C-type	4.14 6.55	0.401-1.498 0.591-0.801	Apr. 1959 Jan. 1961	310
N3	N-S	H-59-B-type	5.60	0.185~1.178	Dec. 1959	170
29	S29°E	Sassa-type	4.2	3.0	Nov. 1952	340
C1	S52°E	H-59-B-type	10	0.064-0.537	Jan. 1960	240
V1	Vertical	V-52-type	4.4	1.12	Dec 1952	350
V2	Vertical	V-59-A-type	4.0	2.20-1.09	Aug. 1959	320
V3	Vertical	V-59-B-type	4.6	0.313~1.541	Dec. 1959	170
V4	Vertical	V-59-C-type	4.0	0.60~1.81	Feb. 1961	370

Table 1 (b)

The Constants of Tiltmeters

Type : Horizontal Pendulum Type

Symbol of Instrument	Direction of Observation	Length of Pendulum	Optical Length of Record	Period	Epoch of Observation	Position of Observation from Ōtsu Entrance
A1	West	5.0 cm	1.8 m	30.0~34.4 sec.	Aug. 1951	370 m.
B1	North	5.0	1.8	30.7-35.2	Aug. 1960	370
A2	West	5.0	2.0	10.2-21.2	Nov. 1960	520
B2	North	5.0	2.0	11.0-20.3	Nov. 1960	520
A3	West	5.0	2.0	27.0-33.2	Dec 1960	180
B3	North	5.0	2.0	28.4-34.8	Dec 1960	180

The instruments which are used in these observatories are shown in Table 1 (a), and Table 1 (b).

The room temperatures are almost constant throughout the year, the amplitudes of their annual variations are about 0.4°C, and the phase lags from the atmospheric temperature of the ground surface is about three months. Fig. 1 shows the temperature at every observatory; in this figure, 1 and 2 are those which are measured with mercurial thermometers of which minimum divisions are 0.1°C at No. 1 Observatory and No. 2 Observatory, respectively, and B–1 and B–3 are the temperature variations which are measured with Beckman's mercurial thermometers of which minimum divisions are 0.01°C at No. 1 Observatory and No. 3 Observatory, respectively.

Fig. 2 shows the variations of linear strains in the direction of N 38°W (L_3, L_2, R_1 and W_1) at No. 2, No. 3 and No. 1 Observatories, respectively, and Fig. 3 does the ones in the direction of east (E_1 and E_3) and in the direction of north (N_1 and N_3) at No. 1 and No. 3 Observatory, respectively, where suffix numbers of their symbols; L_3, L_2,...... etc. show the numbers of the observatories.

The amplitude ratio of annual variation of L_3 and R_1 in the direction of N 38°W is about 3/4, and the interval of the locations of them is about 200 m.. Supposing that the distribution of the linear strain is in a stationary sine wave and that there is no node between the situations of L_3 and R_1, it obtain that the wave length is longer than 1.7 km.. The value is seems to be too large, because the

Fig. 2

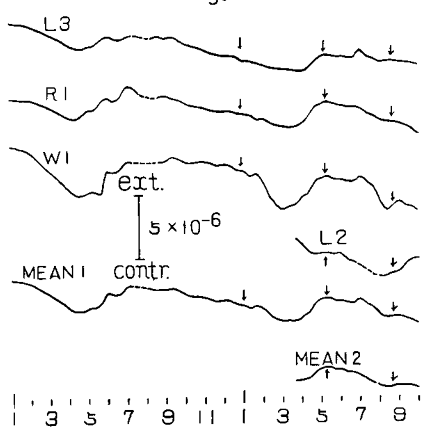


Fig. 3

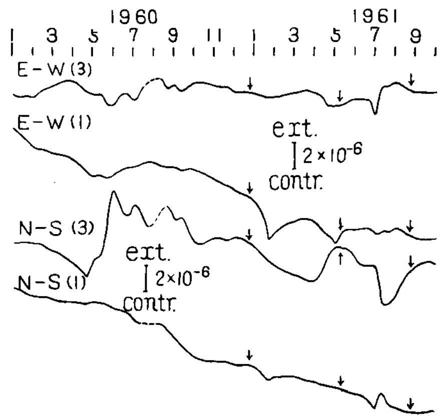


Fig. 4a

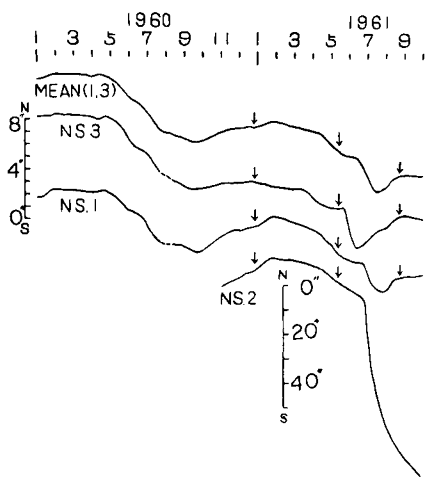
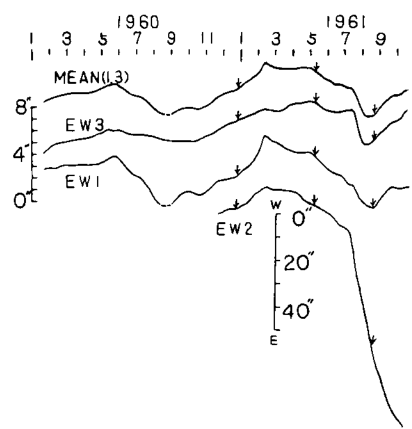


Fig. 4b



phases of L_2 are differ with the ones of W_1, R_1 and L_3 in the many periods. Fig. 4a and 4b show the westward components and northward ones of the ground tilt at No. 1, No. 2 and No. 3 Observatory. No. 2 Observatory is situated near the Ōtani Valley where was sometimes eroded by the floods. At No. 2 Observatory, the tiltmeters recorded the remarkable inclinations toward south-east, after a heavy rainfall, from the end of June, 1961 to the end of October, 1961. And also, it found a long crack stretching over the between of 60 m. and 140 m. from Ōtani-edge in the gallery after the rain.

According to these combined observations, the same components in the every observatory are different each other, but these differences are able to be systematized each other. Therefore, from these observations, it can estimate usefully the orders

Fig. 5a

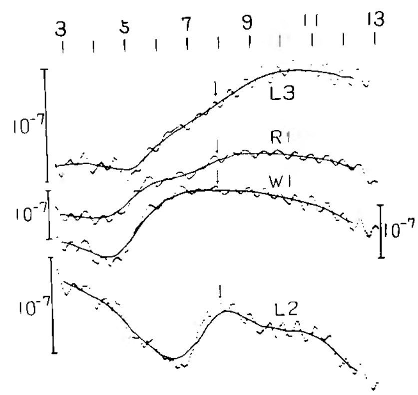


Fig. 8a

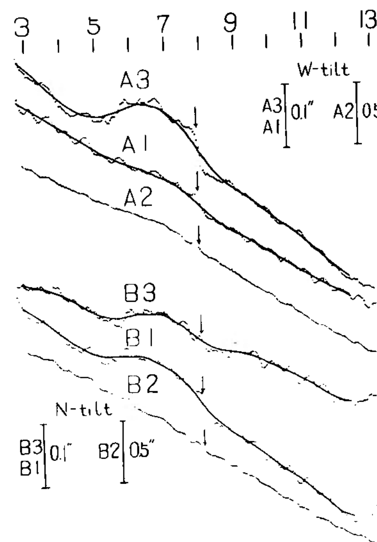


Fig. 6a

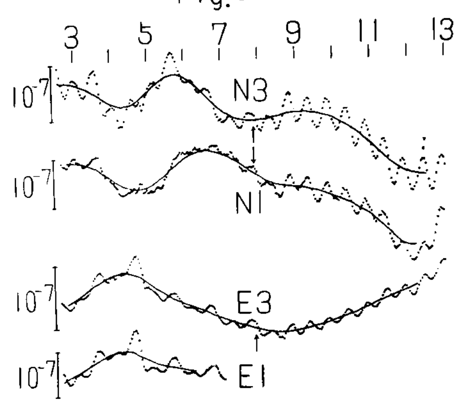
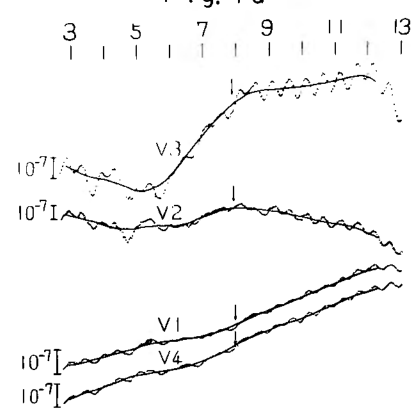


Fig. 7a



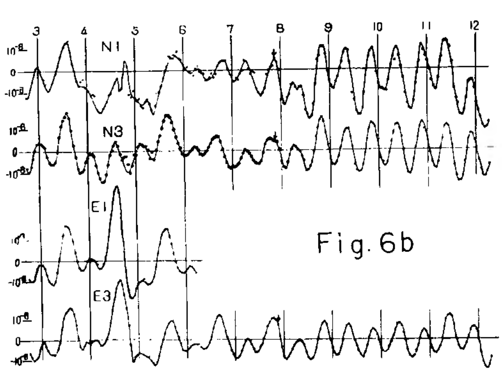


Fig. 6b

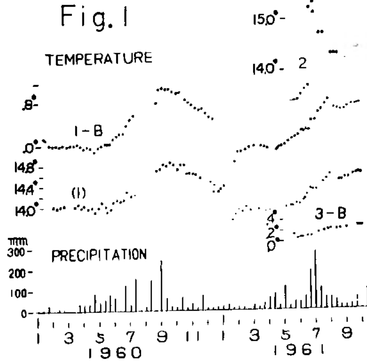


Fig. 1

Fig. 9a

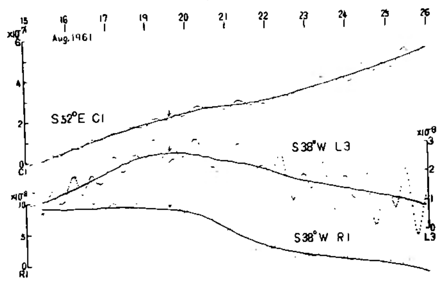


Fig. 9b

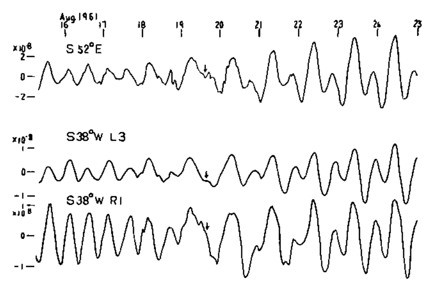


Fig. 10a

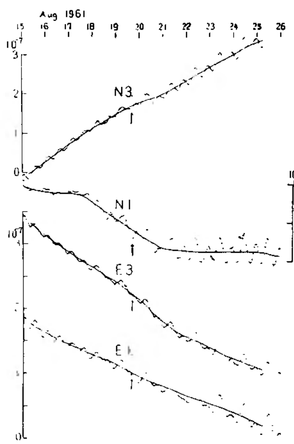


Fig. 10b

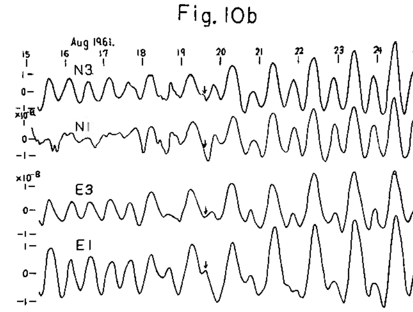


Fig. 11a

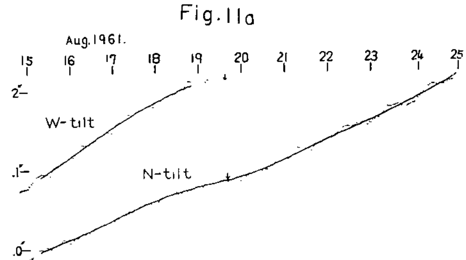
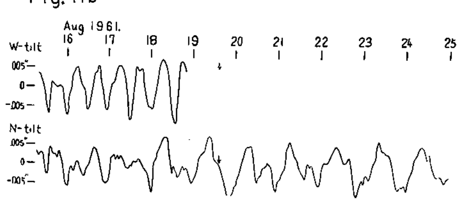


Fig. 11b



of the wave lengths of the deformation.

Next, it has performed the comparison the changes of the equivalent components of the deformations at the every observatory in the short spaces of times before and after the strong earthquakes. As these comparisons should be sometimes performed up to the micro changes so far as 10^{-8} in strain or 10^{-3} second in tilt, the tidal variations should be eliminated from their observed records. Fig. 5a, 6a, 7a and 8a show the crustal strains and the tilts before and after the Himeji Earthquake Swarm (May 7, 1961, Magnitude of the maximum shock: 5.9), respectively. In these figures, the trains of the points show the hourly reading values of the observed records, and the solid lines show their changes which are eliminated the tidal variations from the values by means of Pertsev's method[5] or the deduced method of it. Fig. 6b shows the tidal variations which are extracted from the trains of the reading values on Fig. 6a.

Similarly, Fig. 9a, 10a and 11a show the reading values' curves of the observed records and the smoothed curves which are eliminated the tidal variations from the records before and after the Kitamino Earthquake (August 19, 1961, Magnitude: 7.2) Fig. 9b, 10b and 11b show the tidal variations which are extracted from the reading values-curves.

The seismic intensities (C.M.O. of Japan) are scale III at Osakayama in both of the earthquakes. As these intensities are not so large and the usual changes are large, the remarkable anomalies are not always found in the compensated curves. But, the remarkable anomalies are sometimes found in the extracted tidal variations; it seems that the some parts of the quasi-periodic changes leak from the reading values, and they are supplemented to the tidal curves.

Fig. 12 and 13 show the changes of the ground strains and the tilts in the time of a heavy rainfall of which precipitation is about 70 mm. in a span of four hours, respectively. These anomalous changes due to the rain are very different in observing positions.

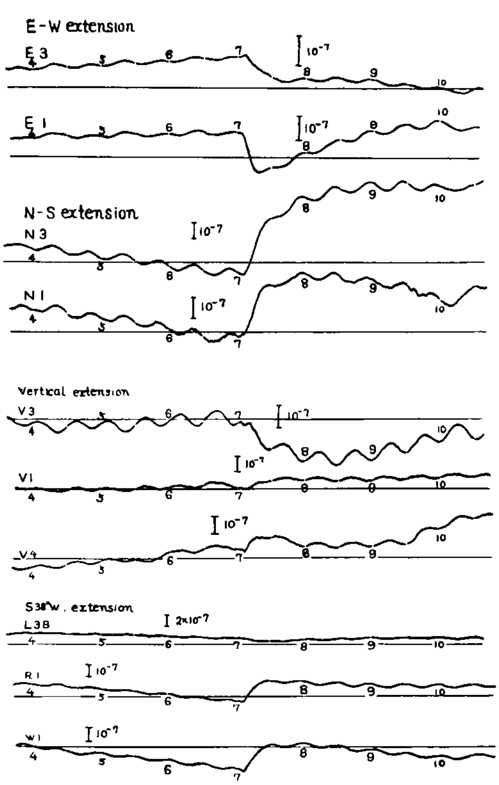


Fig. 12

Conclusion

The combined observations of the crustal deformations at three nearing observatories have been started in Osakayama Observatory on December, 1959. According to these observations, the wave length of annual variation of the crustal strain in the direction of S 38° W is

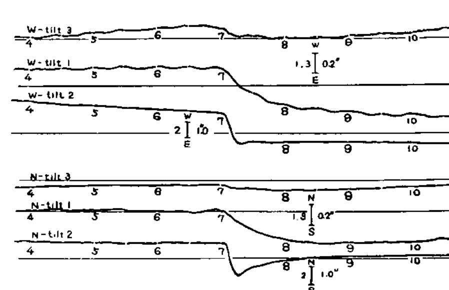


Fig. 13

longer than about 1.7 km. And it seems that the wave lengths of them in the other components are some smaller.

The analyzed anomalies before and after the strong earthquakes (the Himeji Earthquake Swarm and the Kitamino Earthquake) are not always clear because the seismic intensities are not so large. But it appears that the extracted tidal variations are sometimes very anomalous, and the variations of the same components have many points of likeness at every observatory. On the contrary, the anomalies due to the rainfall even in same components are very different each other in different observatories. So it is sure that these observations have an ability to estimate the wave length of the deformations and that to distinguish whether the observed anomalies are the crustal deformations or not.

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